

# Mobile Communications (1)

## Class Overview

Jiro Katto

Dept. of Computer Science and Engineering

E-Mail: [katto@waseda.jp](mailto:katto@waseda.jp)

# Wireless LAN

	802.11	802.11b	802.11a	802.11g	802.11n	802.11ac
year	1997	1999	1999	2003	2009	2014
frequency	2.4GHz	2.4GHz	5GHz	2.4GHz	2.4GHz & 5GHz	5GHz
bitrate	1 – 2 Mbps	1 – 11 Mbps	6 – 54 Mbps	1 – 54 Mbps	1 – 600 Mbps	~ 6.77 Gbps
multiple access, and modulation	DSSS, FH, IrDA	DSSS, CCK	OFDM	DSSS, CCK, OFDM	OFDM, MIMO, channel bonding	OFDM, MIMO, channel bonding

→ 802/11ax

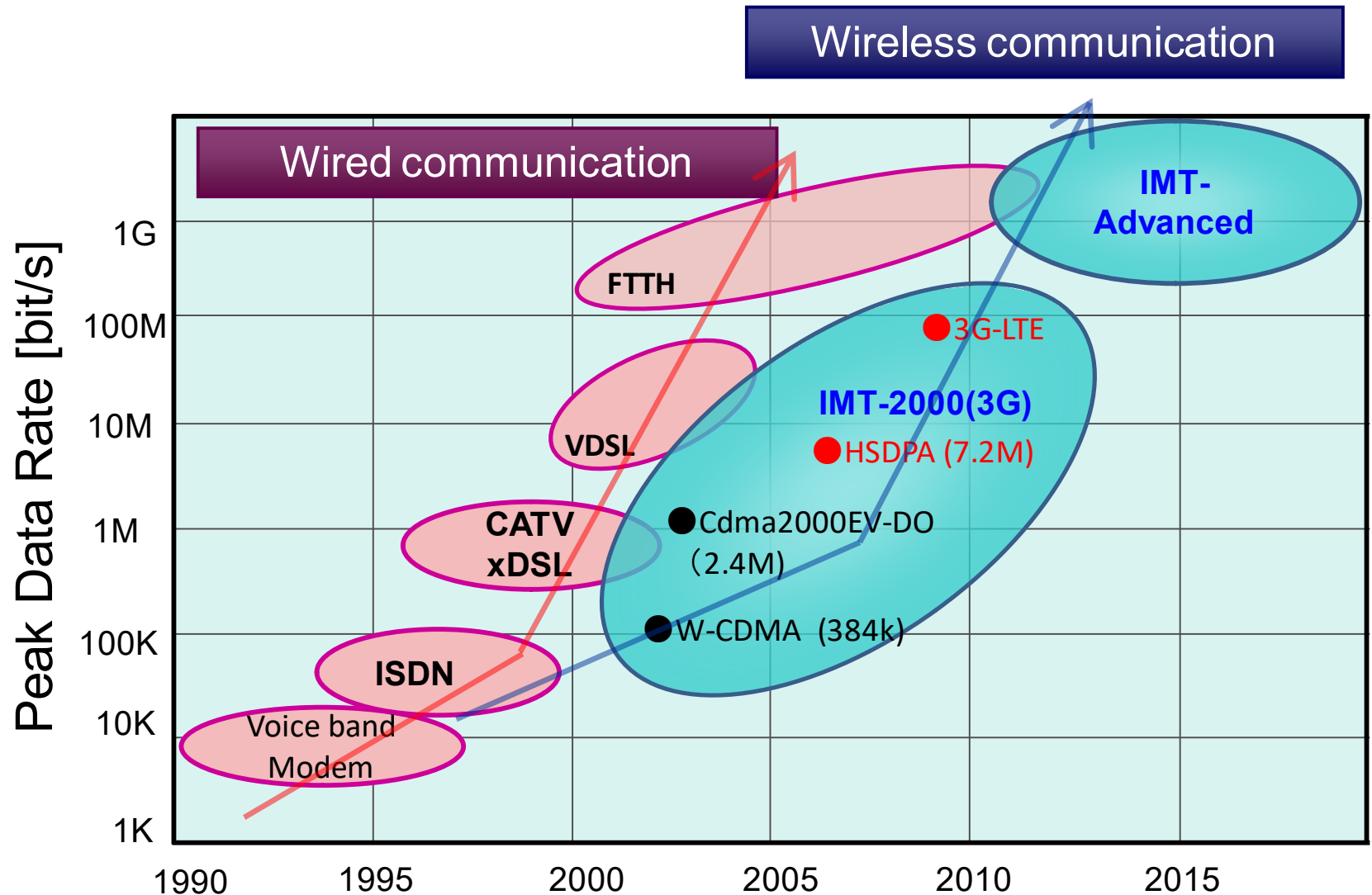
# Wireless PAN/BAN

	802.15.1	802.15.3a	802.15.4a	802.15.4	802.15.6
<b>name</b>	<b>Bluetooth</b>	<b>UWB</b>	<b>UWB</b>	<b>ZigBee</b>	<b>BAN</b>
<b>year</b>	<b>1999</b>	<b>--</b>	<b>2007</b>	<b>2003</b>	<b>2012?</b>
<b>frequency</b>	<b>2.4GHz</b>	<b>3.1 – 10.6GHz</b>	<b>2.4GHz</b>	<b>2.4GHz 868MHz 915MHz</b>	<b>400MHz 2.4GHz</b>
<b>bitrate</b>	<b>720kbps- 24Mbps</b>	<b>480Mbps</b>	<b>1Mbps</b>	<b>20-250 kbps</b>	<b>~10Mbps</b>
<b>multiple access, and modulation</b>	<b>FH GFSK</b>	<b>OFDM or DSSS</b>	<b>DSSS BPSK</b>	<b>DSSS BPSK/QPS K</b>	<b>?</b>
<b>distance</b>	<b>1-100m</b>	<b>4-10m</b>	<b>10m</b>	<b>10-75m</b>	<b>3m</b>
<b>power</b>	<b>1-100mW</b>	<b>&lt; 100mW</b>	<b>1mW</b>	<b>&lt; 60mW</b>	<b>&lt; 1mW?</b>

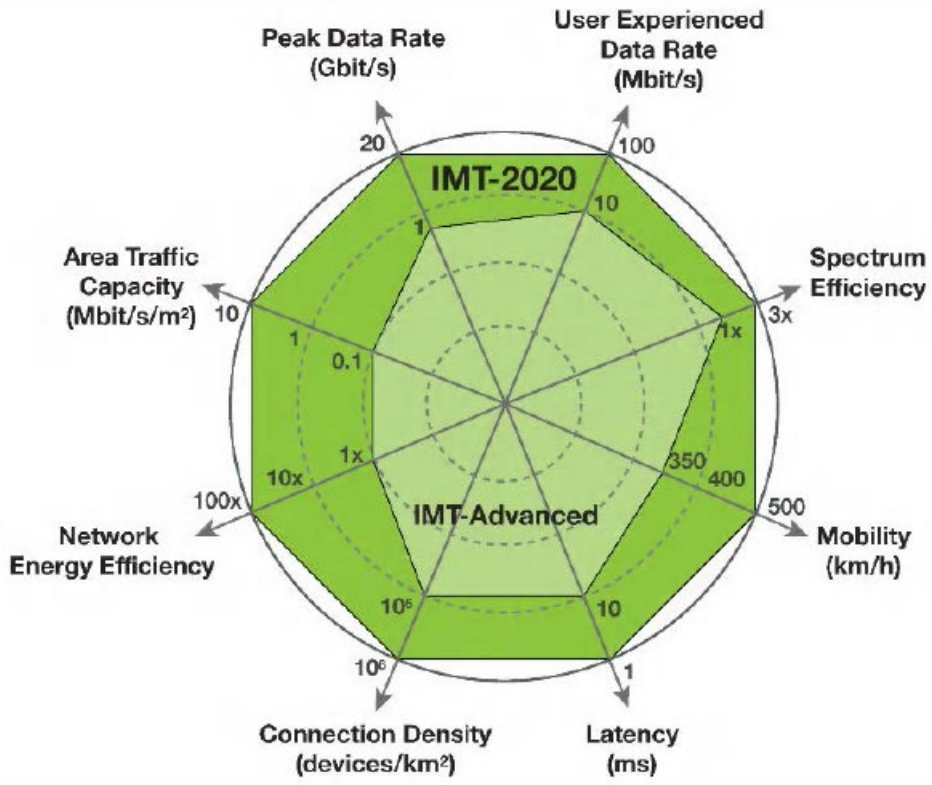
# Cellular

generation	name	frequency	multiple access	modulation	bitrate (downlink)	speech codec
2G	PDC	800MHz / 1.5GHz	FDD-TDMA	$\pi/4$ -DQPSK	9.6 - 28.8 kbps	ACELP, PSI-CELP
	cdmaOne	800MHz	FDD-CDMA	$\pi/4$ -DQPSK	14.4 - 64 kbps	EVRC
	GSM	--	FDD-TDMA	GMSK	9.6 - 171.2 kbps	ACELP
	PHS	1.9GHz	TDD-TDMA	$\pi/4$ -DQPSK	32-256 kbps	ADPCM
3G (IMT-2000)	W-CDMA	800MHz / 1.7GHz / 2GHz	FDD-CDMA	$\pi/4$ -DQPSK	384kbps	AMR
	CDMA2000	800MHz / 2GHz	FDD-CDMA	$\pi/4$ -DQPSK	144kbps	EVRC
3.5G	HSPA	1.7GHz	(W-CDMA)	QPSK~16QAM	1.22 -14 Mbps	--
	EV-DO	800MHz / 2GHz	(CDMA2000)	QPSK~16QAM	2.4 -3.1 Mbps	--
3.9G (Super3G)	LTE	800MHz / 1.5GHz / 2GHz	OFDMA/SD-FDMA/MIMO	QPSK~64QAM	100 - 326.4 Mbps	--
4G (IMT-Advanced)	LTE-Advanced	3.4~3.6GHz	OFDMA/MIMO/CoMP	QPSK~64QAM	~1Gbps	--
5G (IMT-2020)		3.5-4.2GHz, 28GHz	Massive MIMO	QPSK~256QAM ?	~20Gbps ?	

# IMT-Advanced (4G/LTE)



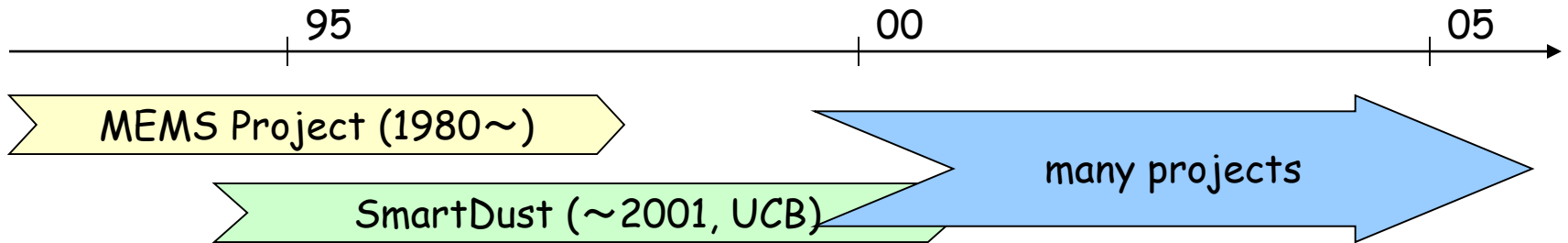
# IMT-2020 (5G)



	IEEE802.11
Peak Rate	<7Gbps
User data rate	Not guaranteed
Spectrum efficiency	Not guaranteed (contention, interference)
Mobility	Pedestrian
Latency	Not guaranteed (network discovery, contention, interference)
Connection density	High (conference rooms, stadia)
Network Energy Efficiency	Not guaranteed (network discovery, contention, interference)
Area Traffic Capacity	High (limited by backhaul)

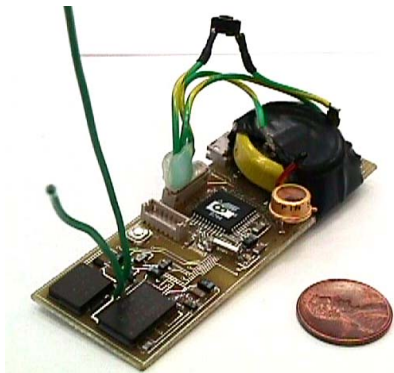
# Sensor Networks

- history



**Sensor(s) + MPU(s) + Networking → On-board → On-chip**

RF Mote



Prototype      ▲ COTS Dust, Tiny OS

Companies      ▲ Crossbow, Dust, Ember, Senticast, ...

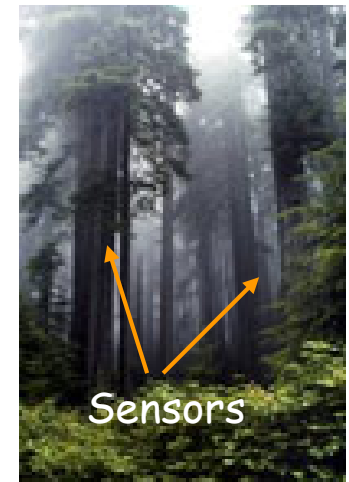
Conferences      ▲ IEEE Sensors, ACM SenSys, ...

Standards      ▲ IEEE 802.15.4 (ZigBee)

# Sensor Networks

- (1) factory
  - (2) maintenance
  - (3) military, national security
  - (4) automation
  - (5) environment monitoring
  - (6) ubiquitous
- 
- (7) smart phone

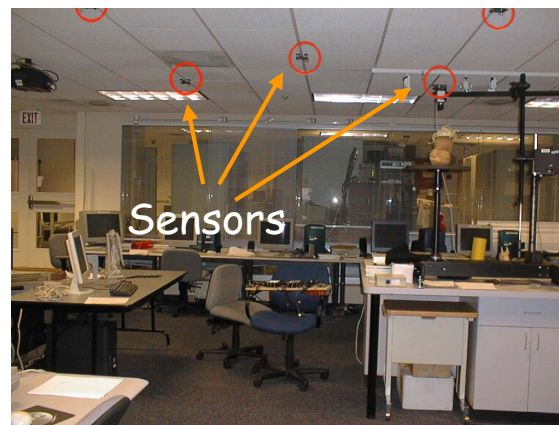
monitoring (UCB)



tracking (UCB)



smart room (MIT)



robot (USC)





# Smart Phone



- Communication
  - 3G/LTE, WiFi, Bluetooth, WiMAX, ...
- Audio and Visual
  - microphone, speaker, camera, display, ...
- Sensors
  - accelerometer, gyroscope, magnetic, proximity, light, temperature, ...

# This Year's Schedule

(tentative)

- 4/12 Class overview
- 4/19 Self Study on CourseN@vi
- 4/26 Radio Communication Basics (1)
- 5/10 Radio Communication Basics (2)
- 5/17 Wireless LAN Standards (1)
- 5/24 Wireless LAN Standards (2)
- 5/31 Implementing Wireless LANs
- 6/07 Wireless LAN Security (1)
- 6/14 Wireless LAN Security (2)
- 6/21 Wireless LAN Troubleshooting
- 6/28 Wireless PAN Standards (1)
- 7/05 Wireless PAN Standards (2)
- 7/12 Wireless MAN Standards
- 7/19 In-class Examination
- 7/26 Self-study on CourseN@vi